COOK

Influence of Lime on the Permeability of Concrete

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# INFLUENCE OF LIME ON THE PERMEABILITY OF CONCRETE



BY

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# THESIS

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

FRANK SAMUEL COOK

ENTITLED INFLUENCE OF LIME ON THE PERMEABILITY OF CONCRETE

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Civil Engineering

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# INTRODUCTION

The demand for impermeable concrete has been growing greater each year, and with this increase in demand there has been increased research and investigation to find some practical way of making the concrete impermeable.

There are four ways of making concrete impermeable:— first, by the use of mechanically graded sand and stone in the proper proportions to form a dense mixture; second, by the use of layers of felt placed on the surface of the concrete and then painted with tar or asphalt, or by the use of layers of felt or steel imbedded in the concrete; third, by plastering the surface of the concrete with some material that is impermeable; fourth, by the addition of some substance to the concrete which will either coat the grains of sand and stone and so keep water from entering the spaces, or fill up the voids in the concrete and thus form a dense mixture.

It is evident that the first method would require a very great amount of time and expense to sift and grade all the sand and stone for a large job.

The second method is also comparatively expensive but it is practical and is used very extensively. However, it is difficult to make layers of felt stick to the concrete while sheets of steel imbedded in a concrete wall will very materially reduce the strength

of the wall.

The objection to the third method lies in the fact that a coat of plaster which is thick enough to be effective against the passage of water will eventually crack and scale off. This is due to the different rates of expansion and contraction between the plaster and the concrete.

The fourth method would be the best if some material could be found which would render the concrete impermeable without reducing its strength. There are companies who claim they have patented material that will fill the above conditions and some of these companies have partially proven their claim.

The writer has taken up the tests of lime as one of that class of materials which fills up the voids in the concrete and thus forms a dense mixture. The purpose of this thesis is to find whether concrete can be made impermeable by the addition of lime, or if not, to determine the effect of the lime on the permeability of the concrete.

## MATERIALS USED

### Cement.

Chicago "AA" Portland cement was used in all of the tests. Twenty-three per cent of water was required for the proper consistency of the neat cement. The tensile briquettes were left under a damp cloth one day and in water six days before being broken.

Tests of Cement. Table I

| Tensile Strength | | Fineness | | |
|---|---|---|---|---|
| Briquette No. | Tensile Strength lb./sq. in. | No. of Sieve | Per cent retained | Per cent passing. |
| 1 | 570 | 74 | 3.0.4 | |
| 2 | 605 | 100 | 6.5.3 | |
| 3 | 565 | 200 | 2.6.3 6 | 73.32 |
| 4 | 625 | | | |
| 5 | 575 | | | |
| 6 | 560 | | | |
| Av. | 583 | | | |

The specific gravity of the cement was 3.160

### Sand and Stone.

The sand was from the Wabash River. It contained a small per cent of clay and was composed mostly of rounded grains. Kankakee limestone of medium quality was used and as can be seen by the following table it contained a comparatively large per cent of dust.

MATERIALS USED

Table II

Sieve Analysis

| Sieve No. | Per cent retained Sand | Stone |
|---|---|---|
| 2 | 0.00 | 0.00 |
| 5 | 2.46 | 24.80 |
| 8 | 6.43 | 23.25 |
| 10 | 7.35 | 11.45 |
| 16 | 22.95 | 16.65 |
| 20 | 4.25 | 3.25 |
| 30 | 19.20 | 5.27 |
| 40 | 13.55 | 2.43 |
| 60 | 15.02 | 2.68 |
| 74 | 3.22 | 1.11 |
| 100 | 3.22 | 1.60 |
| 150 | 0.94 | 1.50 |
| 200 | 0.27 | 0.60 |
| | Per cent passing | |
| 200 | 0.72 | 7.30 |
| Specific Gravity | 2.665 | 2.690 |

Lime

The lime was manufactured by the "Marblehead Lime Co." and was the kind ordinarily used in brick mortar. The specific gravity of the lime was 2.936

## DESCRIPTION OF APPARATUS

Simple hand tools were used for mixing the concrete and iron rings six inches in diameter and two inches deep were used for molds. These rings, after being filled were left under a damp cloth for one day and then placed in a damp chamber for six days.

At the end of a week the rings were clamped between the two heavy iron plates of the permeability apparatus shown in Figure I

The permeability apparatus was connected to the University water-main by the small pipe "A" (Figure 1.) which gave an average pressure of forty-five pounds per square inch.

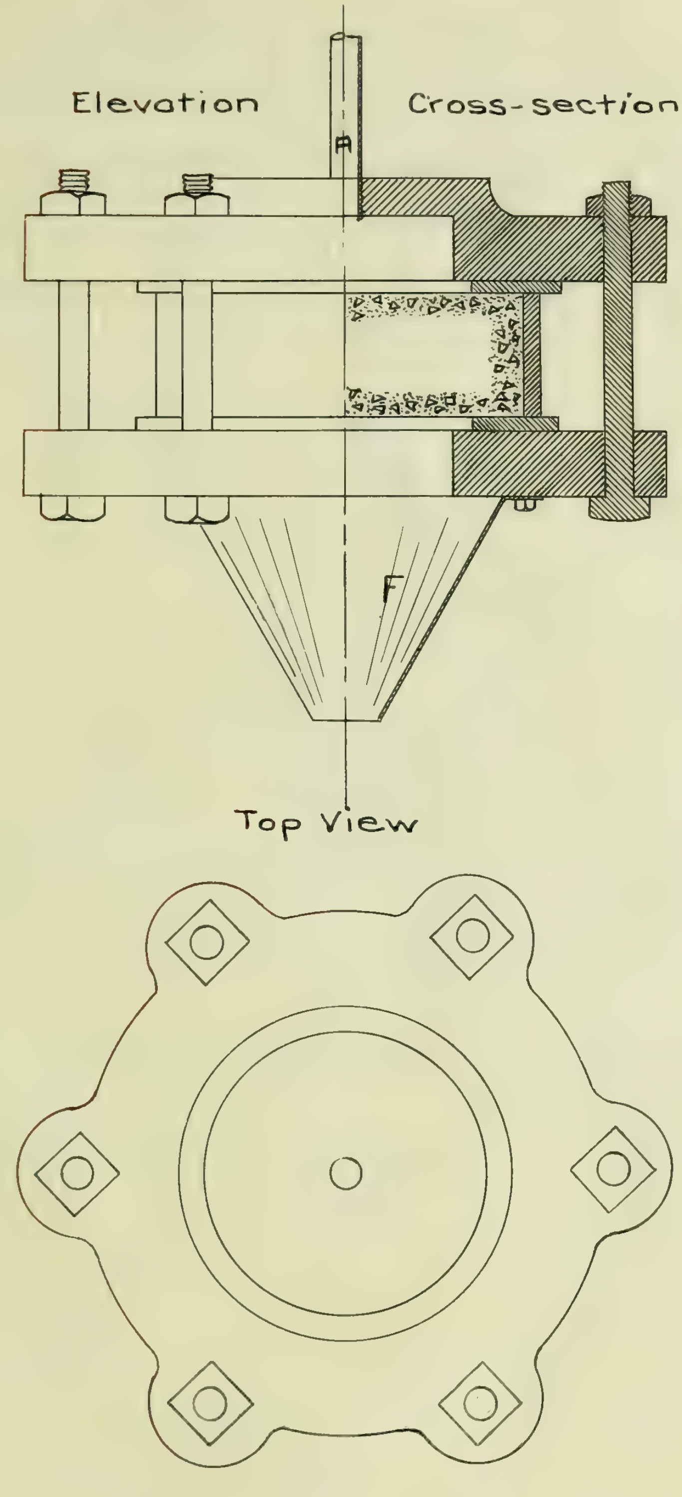
Rubber gaskets formed the joints between the disk and the plates, and a surface four inches in diameter was left exposed to the pressure of the water. The gaskets, alone, did not prove satisfactory and in order to make the joints perfectly water-tight, hot asphalt was spread on those parts of the disk which the gaskets covered.

The water which passed through the concrete was collected in flasks under the funnel "F".

The apparatus for finding the specific gravity of the materials consisted of a fine balance and a liquid displacement flask in which kerosene was used.

FIGURE I

# PERMEABILITY APPARATUS




Scale, 1 inch = 4 inches

# VOLUMETRIC TESTS

A volumetric test was made of each specimen in order to determine its per cent of voids. No special apparatus was used in this connection but the measurements were made in the iron rings.

The rings were weighed before and after filling to determine the weight of materials used. The weight was checked by mixing the concrete in a pan and finding the amount left over.

The weight of each material in the ring was found by multiplying the total weight of the material by the per cent of the whole mixture used in the ring. The space occupied by each material in the ring was found by dividing the weight of that material by its specific gravity. Knowing the volume of the materials and of the ring, the per cent of voids was easily obtained.

In determining the per cent of voids the space occupied by water was entirely neglected. The relsuts of the volumetric tests are shown in Table III.

# VOLUMETRIC TESTS

## Table III

| Disk No. | Proportion to Cement | | | | | Per cent of Voids |
|---|---|---|---|---|---|---|
| | Cement | Sand | Stone | Lime | Water | |
| 11 | 1 | 3 | 6 | 0.00 | 1.00 | 33.1 |
| 12 | 1 | 3 | 6 | 0.00 | 1.00 | 34.8 |
| 13 | 1 | 3 | 6 | 0.23 | 1.67 | 22.3 |
| 14 | 1 | 3 | 6 | 0.23 | 1.67 | 24.1 |
| 15 | 1 | 2 | 4 | 0.00 | 0.77 | 26.3 |
| 16 | 1 | 2 | 4 | 0.00 | 0.77 | 24.8 |
| 17 | 1 | 2 | 4 | 0.50 | 0.88 | 23.7 |
| 18 | 1 | 2 | 4 | 0.50 | 0.88 | 22.9 |
| 19 | 1 | 2 | 4 | 0.50 | 1.76 | 25.2 |
| 20 | 1 | 2 | 4 | 0.00 | 0.77 | 23.3 |
| 21 | 1 | 2 | 4 | 0.39 | 1.23 | 30.6 |
| 22 | 1 | 2 | 4 | 0.00 | 0.77 | 22.7 |
| 23 | 1 | 2 | 4 | 0.75 | 1.82 | 32.7 |

# RESULTS

Table V gives the results from all the permeabitity tests. For convenience in comparison the proportion of each material is expressed in terms of the weight of the cement.

Under "Readings" (Table IV) is given the amount of water in grams with the date and time of day at which each reading was taken. The percolation in grams per square inch per day is shown in Table V.

Plate I shows the effect of lime upon the tensile strength of cement mortar. which consisted of one part cement to three parts sand. It is quite probable that the effect of lime upon the tensile strength of the concrete is about the same as upon that of the mortar.

# TABLE IV

| Disk No. | Test started Date | Readings | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1st. dy. | | 2nd. dy. | | 3rd. dy. | | 4th. dy. | | 5th. dy. | | 6th. dy. | | 7th. dy. | | 8th. dy. | |
| | | Date | Amount | Date | Amount | Date | Amount | Date | Amount | Date | Amount | Date | Amount | Date | Amount | Date | Amount |
| 1 | 1/16 3.00 | 1/16 5.00 | 234 | 1/17 1.00 | 500+ | 1/18 3.45 | 550 | 1/19 2.00 | 295 | 1/20 3.35 | 250 | 1/21 1.50 | 175 | 1/22 3.15 | 157 | 1/23 8.30 | 100 |
| 2 | 1/16 3.00 | 1/16 5.00 | 59 | 1/17 1.00 | 250+ | 1/18 3.45 | 250+ | 1/19 2.00 | 148 | 1/20 3.35 | 118 | 1/21 1.50 | 74 | 1/22 3.15 | 71 | 1/23 8.30 | 44 |
| 3 | 1/16 3.00 | 1/16 5.00 | 54 | 1/17 1.00 | 250+ | 1/18 3.45 | 239 | 1/19 2.00 | 118 | 1/20 3.35 | 94 | 1/21 1.50 | 56 | 1/22 3.15 | 50 | 1/23 8.30 | 31 |
| 4 | 1/16 3.00 | 1/16 5.00 | 87 | 1/17 1.00 | 500+ | 1/18 3.45 | 248 | 1/19 2.00 | 127 | 1/20 3.35 | 108 | 1/21 1.50 | 69 | 1/22 3.15 | 63 | 1/23 8.30 | 40 |
| 5 | 1/23 11.00 | 1/23 3.00 | 287 | 1/24 9.00 | 350 | 1/25 9.00 | 140 | 1/25 2.40 | 12 | 1/26 3.30 | 56 | 1/27 4.30 | 40 | 1/28 1.00 | 23 | 1/29 4.00 | 27 |
| 6 | 1/23 11.00 | 1/23 3.00 | 97 | 1/24 9.00 | 285 | 1/25 9.00 | 150 | 1/25 2.40 | 15 | 1/26 3.30 | 60 | 1/27 4.30 | 46 | 1/28 1.00 | 28 | 1/29 4.00 | 29 |
| 7 | 2/13 4.30 | 2/15 8.30 | 1980 | 2/16 8.30 | 350 | 2/17 9.30 | 243 | 2/18 8.30 | 170 | 2/19 9.00 | 162 | 2/20 1.30 | 145 | — | | — | |
| 8 | 2/13 4.30 | 2/15 8.30 | 142 | 2/16 8.30 | 25 | 2/17 9.30 | 18 | 2/18 8.30 | 12 | 2/19 9.00 | 11 | 2/20 1.30 | 9 | — | | — | |
| 9 | 2/20 5.00 | 2/22 9.30 | 1950 | 2/23 9.00 | 397 | 2/24 9.00 | 275 | 2/25 8.30 | 183 | 2/26 10.00 | 157 | 2/27 2.00 | 145 | — | | — | |
| 10 | 2/20 5.00 | 2/22 9.30 | 242 | 2/23 9.00 | 40 | 2/24 9.00 | 37 | 2/25 8.30 | 21 | 2/26 10.00 | 12 | 2/27 2.00 | 10 | — | | — | |
| 11 | 2/27 4.00 | — | | — | | — | | — | | — | | — | | — | | — | |
| 12 | 2/27 4.00 | — | | — | | — | | — | | — | | — | | — | | — | |
| 13 | 2/27 4.00 | 3/1 9.00 | 2750 | 3/2 8.45 | 108 | 3/3 10.00 | 858 | 3/4 9.30 | 600 | 3/5 10.00 | 575 | 3/6 1.00 | 565 | — | | — | |
| 14 | 2/27 4.00 | 3/1 9.00 | 2450 | 3/2 8.45 | 800 | 3/3 10.00 | 667 | 3/4 9.30 | 475 | 3/5 10.00 | 475 | 3/6 1.00 | 466 | — | | — | |
| 15 | 3/27 3.30 | 3/29 8.00 | 1056 | 3/30 8.00 | 242 | 3/31 4.00 | 208 | 3/32 4.30 | 72 | 3/33 4.00 | 109 | 3/34 9.00 | 59 | — | | — | |
| 16 | 3/27 3.30 | 3/29 8.00 | 824 | 3/30 9.00 | 171 | 3/31 4.00 | 137 | 3/32 9.30 | 52 | 3/33 4.00 | 81 | 3/34 9.00 | 43 | — | | — | |
| 17 | 3/27 3.30 | 3/29 8.00 | 510 | 3/30 9.00 | 217 | 3/31 4.00 | 193 | 3/32 9.30 | 59 | 3/33 4.00 | 82 | 3/34 9.00 | 41 | — | | — | |
| 18 | 3/27 3.30 | 3/29 8.00 | 635 | 3/30 9.00 | 273 | 3/31 4.00 | 284 | 3/32 9.30 | 95 | 3/33 4.00 | 145 | 3/34 9.00 | 81 | — | | — | |
| 19 | 4/3 10.00 | 4/5 10.00 | 1630 | 4/6 9.30 | 1421 | 4/7 9.00 | 1203 | 4/8 9.00 | 975 | 4/9 11.00 | 839 | 4/10 9.00 | 792 | — | | — | |
| 20 | 4/3 10.00 | 4/5 10.00 | 773 | 4/6 9.30 | 108 | 4/7 9.00 | 62 | 4/8 9.00 | 50 | 4/9 11.00 | 40 | 4/10 9.00 | 31 | — | | — | |
| 21 | 4/3 10.00 | 4/5 10.00 | 1451 | 4/6 9.30 | 312 | 4/7 9.00 | 214 | 4/8 9.00 | 160 | 4/9 11.00 | 140 | 4/10 9.00 | 50 | — | | — | |
| 22 | 4/19 10.30 | 4/20 9.30 | 367 | 4/21 10.00 | 163 | 4/22 1.00 | 117 | 4/23 11.00 | 52 | 4/24 10.30 | 42 | 4/26 10.30 | 75 | 4/27 9.00 | 27 | — | |
| 23 | 4/19 10.30 | 4/20 9.30 | 73 | 4/21 10.00 | 43 | 4/22 1.00 | 37 | 4/23 11.00 | 13 | 4/24 10.30 | 7 | 4/26 10.30 | — | 4/27 9.00 | — | — | |

# TABLE V

| Disk No. | Age during test dys | Composition: Proportion to Cement — Cement | Sand | Stone | Lime | Water | Voids per cent | Percolation in grams per sq. in. per dy. — 1st dy. | 2nd dy. | 3rd dy. | 4th dy. | 5th dy. | 6th dy. | 7th dy. | Total for 7dys. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7-14 | 1 | 2 | 4 | 0.00 | 0.77 | — | 45 | 39 | 25 | 19 | 15 | 12 | 11 | 166 |
| 2 | 7-14 | 1 | 2 | 4 | 0.13 | 0.85 | — | 29 | 21 | 13 | 9 | 6 | 5 | 4 | 87 |
| 3 | 7-14 | 1 | 2 | 4 | 0.26 | 0.97 | — | 22 | 17 | 10 | 7 | 5 | 4 | 3 | 68 |
| 4 | 7-14 | 1 | 2 | 4 | 0.39 | 1.23 | — | 24 | 18 | 10 | 8 | 6 | 5 | 4 | 75 |
| 5 | 7-14 | 1 | 2 | 4 | 0.00 | 0.77 | — | 56 | 11 | 4 | 3 | 2 | 2 | 2 | 80 |
| 6 | 7-14 | 1 | 2 | 4 | 0.35 | 1.05 | — | 33 | 12 | 10 | 4 | 2 | 2 | 1 | 64 |
| 7 | 7-14 | 1 | 2 | 4 | 0.00 | 0.77 | — | 96 | 63 | 28 | 19 | 14 | 12 | 9 | 244 |
| 8 | 7-14 | 1 | 2 | 4 | 0.32 | 1.10 | — | 7 | 5 | 2 | 1 | 1 | .9 | .6 | 17½ |
| 9 | 7-14 | 1 | 2 | 4 | 0.00 | 0.77 | — | 92 | 63 | 32 | 22 | 15 | 12 | 10 | 245 |
| 10 | 7-14 | 1 | 2 | 4 | 0.29 | 1.12 | — | 12 | 8 | 3 | 3 | 2 | 1 | .6 | 29½ |
| 11 | 7-14 | 1 | 3 | 6 | 0.00 | 1.00 | 33.1 | — | — | — | — | — | — | — | — |
| 12 | 7-14 | 1 | 3 | 6 | 0.00 | 1.00 | 34.8 | — | — | — | — | — | — | — | — |
| 13 | 7-14 | 1 | 3 | 6 | 0.23 | 1.67 | 22.3 | 129 | 111 | 81 | 65 | 49 | 45 | 40 | 520 |
| 14 | 7-14 | 1 | 2 | 4 | 0.23 | 1.67 | 24.1 | 114 | 92 | 65 | 50 | 38 | 36 | 33 | 428 |
| 15 | 7-14 | 1 | 2 | 4 | 0.00 | 0.77 | 26.3 | 50 | 32 | 18 | 13 | 8 | 7 | 7 | 135 |
| 16 | 7-14 | 1 | 2 | 4 | 0.00 | 0.77 | 24.8 | 39 | 23 | 13 | 8 | 6 | 5 | 4 | 98 |
| 17 | 7-14 | 1 | 2 | 4 | 0.50 | 0.88 | 23.7 | 24 | 19 | 16 | 12 | 6 | 5 | 5 | 87 |
| 18 | 7-14 | 1 | 2 | 4 | 0.50 | 0.88 | 22.9 | 30 | 23 | 19 | 17 | 10 | 9 | 8 | 114 |
| 19 | 7-14 | 1 | 2 | 4 | 0.50 | 1.76 | 25.2 | 159 | 134 | 116 | 98 | 77 | 72 | 69 | 705 |
| 20 | 7-14 | 1 | 2 | 4 | 0.00 | 0.77 | 23.3 | 31 | 19 | 9 | 5 | 4 | 3 | 3 | 72 |
| 21 | 7-14 | 1 | 2 | 4 | 0.39 | 1.23 | 30.6 | 58 | 40 | 25 | 17 | 13 | 9 | 4 | 166 |
| 22 | 7-14 | 1 | 2 | 4 | 0.00 | 0.77 | 22.7 | 31 | 13 | 9 | 5 | 3 | 3 | 2 | 66 |
| 23 | 7-14 | 1 | 2 | 4 | 0.75 | 1.82 | 32.7 | 6 | 3 | 3 | 1 | .6 | — | — | 13½+ |

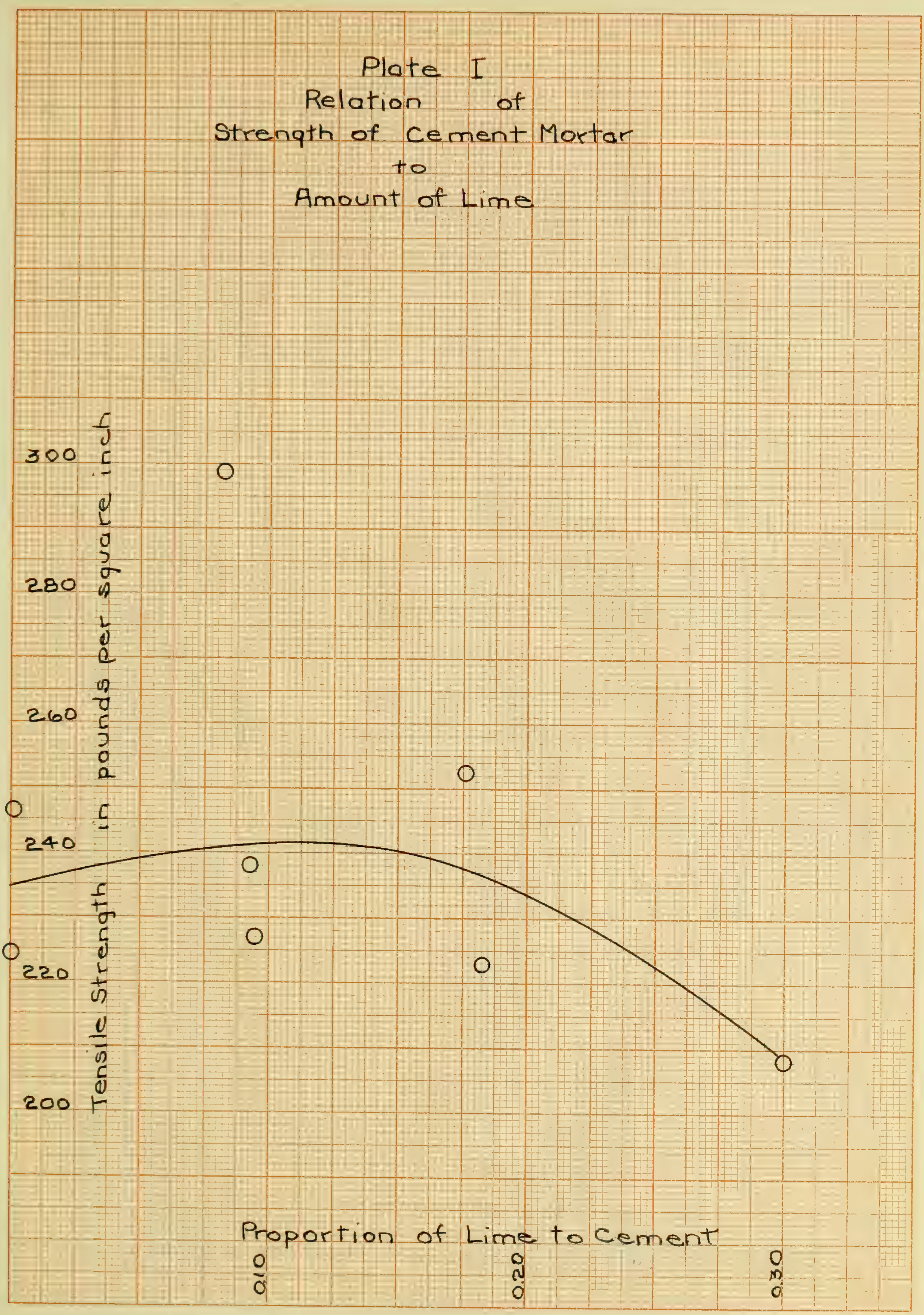


Plate I
Relation of
Strength of Cement Mortar
to
Amount of Lime
300
280
260
240
220
200
Tensile Strength in pounds per square inch
Proportion of Lime to Cement
0.10
0.20
0.30

## RESULTS

The results of the tests show that it is practically impossible to get impermeable concrete by the use of lime. From Plate II it is seen that the least degree of permeability is secured when the proportion of lime to cement is about 0.30 to 1.00. This amount gives a percolation of 0.60 gram per square inch at the end of seven days while at the end of fourteen days the percolation was only 0.24 gram.

Disks 11-14 were the only ones made having the proportions of one part cement, three parts sand, and six parts stone. These four disks showed conclusively that richer mixtures must necessarily be used for anything approaching impermeable concrete.

The "puddling" effect of water upon concrete is clearly shown by Plate III. In the case of disk no. 8 the percolation decreased from 9.0 grams during the first day to 0.60 gram on the seventh. This gradual decrease in percolation is evidently not caused by the presence of lime for the decrease is proportionally the same in those disks which do not contain lime.

It is plain that any material used in concrete to decrease permeability should not decrease the strength. Plate III shows that when the proportion of lime to cement was 0.15 to 1.00 the strength of the mortar was increased about thirty per cent but increasing proportions of lime caused a gradual decrease in

## RESULTS

the tensile strength. As has been stated the most effective proportion of lime to cement in reducing permeability was about 0.30 to 1.00 and with that proportion the strength of the mortar was reduced about eleven per cent below the strength of mortar without lime.

For practical purposes this reduction in strength would not be prohibitive and since lime considerably reduced the permeability of concrete it would be a cheap and effective material to use where a reduced permeability but not strict impermeability of the concrete is required.

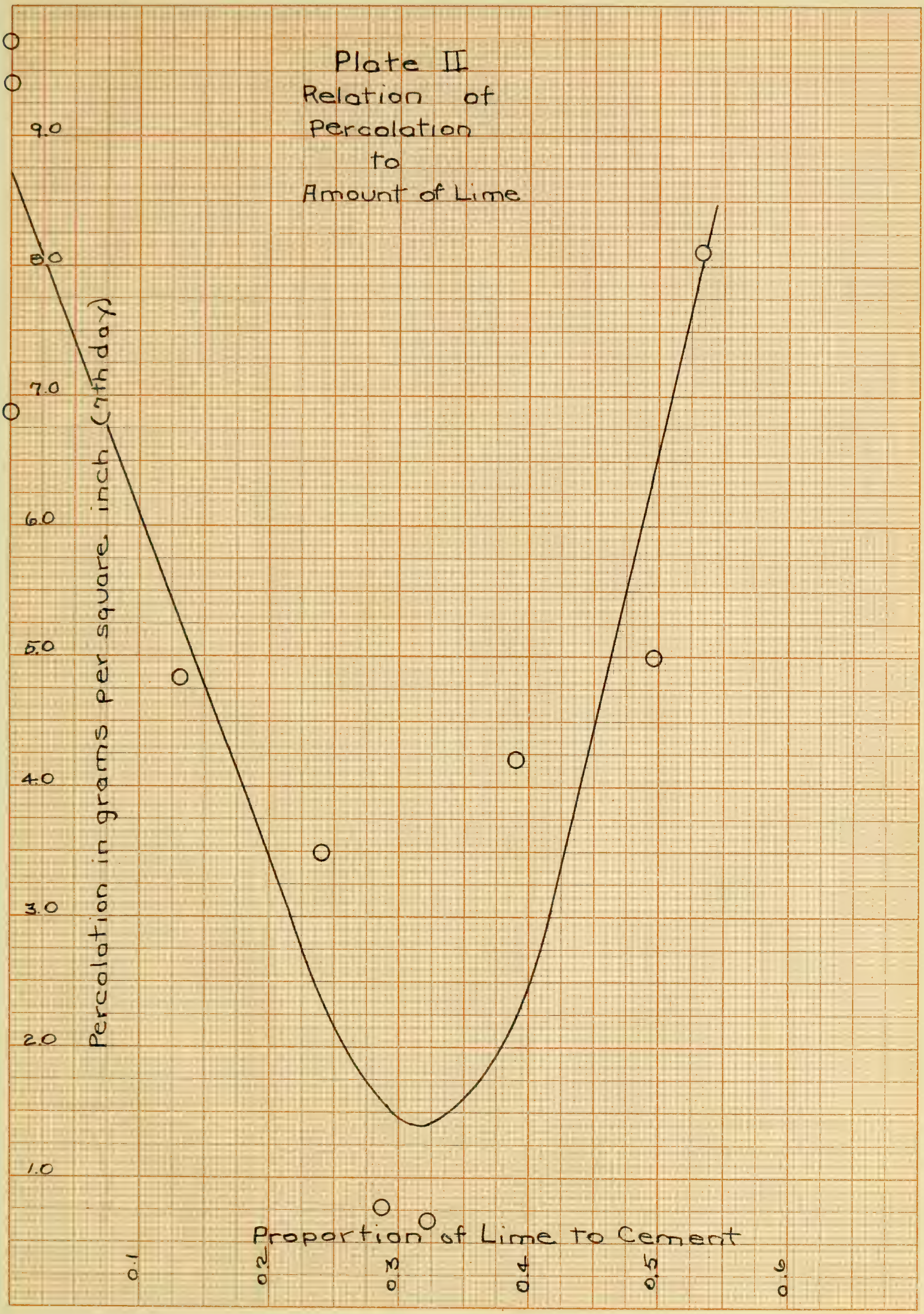


Plate II
Relation of
Percolation
to
Amount of Lime
Percolation in grams per square inch (7th day)
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Proportion of Lime to Cement
0.1
0.2
0.3
0.4
0.5
0.6

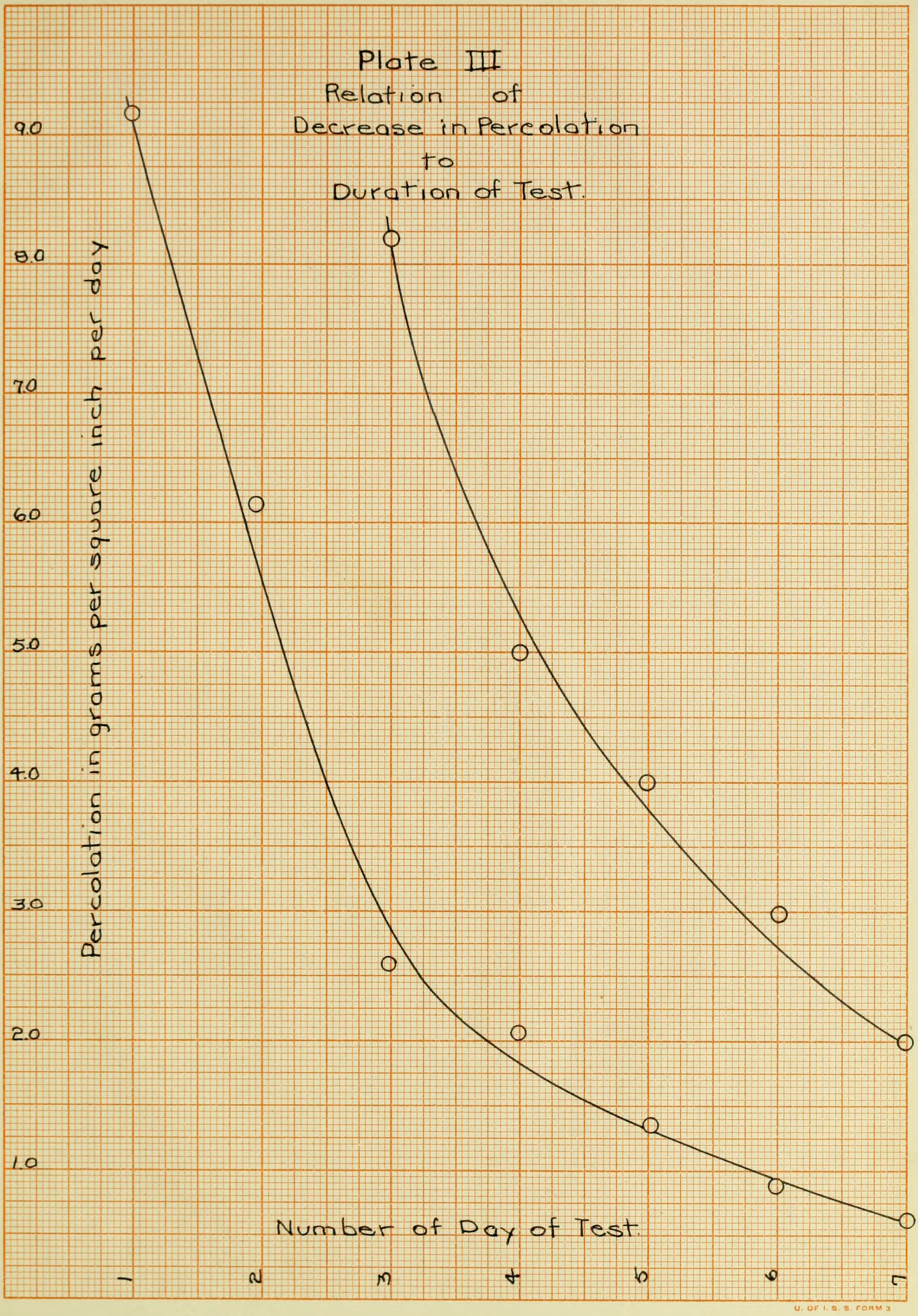


Plate III
Relation of
Decrease in Percolation
to
Duration of Test.
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Percolation in grams per square inch per day
Number of Day of Test.
1
2
3
4
5
6
7
U. OF I. S. S. FORM 3